

PCT

WORLD INTELLECTUAL PROPERTY ORGANIZATION  
International Bureau



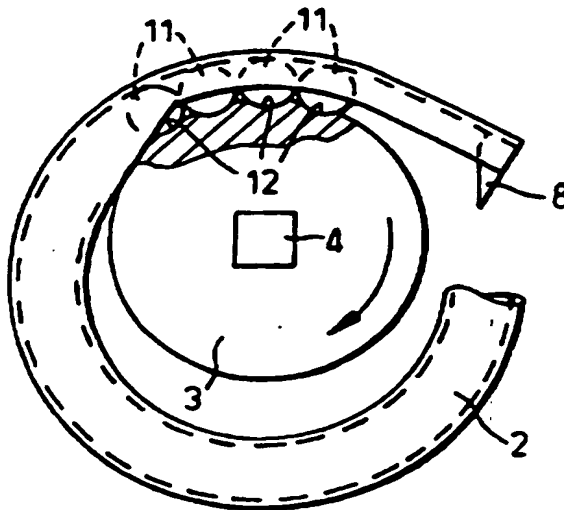
INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification <sup>6</sup> : <b>B60R 22/46</b>		A2	(11) International Publication Number: <b>WO 96/25310</b>
			(43) International Publication Date: 22 August 1996 (22.08.96)
(21) International Application Number: <b>PCT/GB96/00327</b>		(81) Designated States: JP, KP, KR, MX, US, European patent (AT, BE, CH, DE, DK, ES, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).	
(22) International Filing Date: 15 February 1996 (15.02.96)		<p>Published</p> <p><i>Without international search report and to be republished upon receipt of that report.</i></p>	
(30) Priority Data: 9503070.6      16 February 1995 (16.02.95)      GB			
(71) Applicant (for all designated States except US): ROYAL ORD- NANCE PLC [GB/GB]; Euxton Lane, Euxton, Chorley, Lancs PR7 6AD (GB).			
(72) Inventor; and (75) Inventor/Applicant (for US only): HICKEY, Dennis, James [GB/GB]; Inglenook, Poplar Avenue, Longton, Nr Preston, Lancashire PR4 5PA (GB).			
(74) Agent: WILDMAN, D. B.; Royal Ordnance plc, Patents & Licensing Dept., Egyptian House, 170-173 Piccadilly, London W1V 9DD (GB).			

(54) Title: VEHICLE OCCUPANT RESTRAINT SYSTEM

(57) Abstract

A pretensioner for a vehicle seat belt retractor of the type having a rotatable take-up reel on which seat belt webbing can be wound, which comprises: (i) an elongate pressure chamber (2); (ii) a plurality of projectiles (11) located in the pressure chamber; (iii) gas generating means (5) for generating a high-pressure gas within the pressure chamber so as to propel the projectile along the pressure chamber; (iv) a drive surface (12; 21; 25; 34; 41) upon which the projectiles impinge when propelled along the pressure chamber by the high-pressure gas, the drive surface being connected to, or comprising a part of, the rotatable take-up reel (42) of the vehicle seat belt retractor and arranged to be driven by the impinging projectiles (11) so as to rotate the rotatable take-up reel in a belt retraction direction when impinged upon by the projectiles, so as, in operation, to take up slack in the seat belt webbing, and to pull the seat belt webbing against the vehicle occupant.



BEST AVAILABLE COPY

**FOR THE PURPOSES OF INFORMATION ONLY**

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AM	Armenia	GB	United Kingdom	MW	Malawi
AT	Austria	GE	Georgia	MX	Mexico
AU	Australia	GN	Guinea	NE	Niger
BB	Barbados	GR	Greece	NL	Netherlands
BE	Belgium	HU	Hungary	NO	Norway
BF	Benin	IE	Ireland	NZ	New Zealand
BG	Bulgaria	IT	Italy	PL	Poland
BJ	Benin	JP	Japan	PT	Portugal
BR	Brazil	KE	Kenya	RO	Romania
BY	Belarus	KG	Kyrgyzstan	RU	Russian Federation
CA	Canada	KP	Democratic People's Republic of Korea	SD	Sudan
CF	Central African Republic	KR	Republic of Korea	SE	Sweden
CG	Congo	KZ	Kazakhstan	SG	Singapore
CH	Switzerland	LI	Liechtenstein	SI	Slovenia
CI	Côte d'Ivoire	LK	Sri Lanka	SK	Slovakia
CM	Cameroon	LR	Liberia	SN	Senegal
CN	China	LT	Lithuania	SZ	Swaziland
CS	Czechoslovakia	LU	Luxembourg	TD	Chad
CZ	Czech Republic	LV	Latvia	TG	Togo
DE	Germany	MC	Monaco	TJ	Tajikistan
DK	Denmark	MD	Republic of Moldova	TT	Trinidad and Tobago
EE	Estonia	MG	Madagascar	UA	Ukraine
ES	Spain	ML	Mali	UG	Uganda
FI	Finland	MN	Mongolia	US	United States of America
FR	France	MR	Mauritania	UZ	Uzbekistan
GA	Gabon			VN	Viet Nam

### Vehicle Occupant Restraint System

This invention relates to vehicle occupant restraint systems and more particularly to a seat belt pretensioner for taking up slack in a seat belt in the event of a vehicle collision.

A typical inertia reel seat belt comprises a reel of webbing fitted at one end with a locking device that only functions if the reel spins too quickly. During a collision, standard inertia reel seat belts will typically allow 120 to 200 mm of slack before the locking mechanism functions. Devices which are more sensitive than this are impractical when the user unreels the belt to lock it into position in normal use. The delay in operation can allow the occupant to move out of the seat before being arrested and whilst this may avoid a fatality, it can lead to serious whiplash injuries.

Seat belt pretensioners are now widely used in vehicles to provide additional protection to the occupants in the event of a collision. They are normally connected to collision-sensing devices and use stored energy to wind in sufficient slack in the belt to lock the belt before the user can begin to move. The energy can be stored in the form of a spring or in a pyrotechnic gas-generating composition.

In a typical application, the function of the seat belt pretensioner is to rotate the seat belt retractor or take-up reel rapidly in a belt retraction direction to pull the belt against the vehicle occupant and eliminate slack in the belt. Many such pretensioner devices have been proposed, and exemplary of such prior art constructions are those disclosed in US patents numbers 4178016, 4789185 and 5145209; European patent number 0480137; German patent application number DE3715845 and UK patent application number 2258603. The entire disclosures of these prior art patents are incorporated herein by reference.

The technical requirements for a seat belt pretensioner are very numerous. Firstly it must not interfere with the normal operation of the inertia reel seat belt retractor. Secondly it must be capable of activation within a few milliseconds in order to provide adequate protection to the vehicle occupant in the event of a collision. Thirdly, vehicle manufactures' specifications now require that the pretensioner should exert a force of 700 to 800 Newtons and retract the seat belt by a minimum of 100 mm and a maximum of 200 mm. Fourthly, after activation of the seat belt pretensioner, it should preferably not interfere with the normal operation of the inertia reel seat belt retractor, in the event that the vehicle can still be driven after the collision incident.

Further very important practical requirements are that the seat belt pretensioner should be highly compact, fit on to existing inertia reel seat belt systems and preferably fit the housing profile of existing equipment.

Seat belt pretensioners which have been proposed hitherto either do not meet the technical requirements outlined above, or are unacceptably bulky or impractical.

According to the present invention there is provided a pretensioner, for example, for an inertia reel seat belt, wherein the motive force is provided by a projectile impinging upon a drive surface.

In one aspect of the invention, there is provided a pretensioner for a vehicle seat belt retractor of the type having a rotatable take-up reel on which seat belt webbing can be wound, which comprises:

- 10 (i) An elongate pressure chamber;
- (ii) a plurality of projectiles located in the pressure chamber;
- (iii) gas generating means for generating a high-pressure gas within the pressure chamber so as to propel the projectiles along the pressure chamber; and
- 15 (iv) a drive surface upon which the projectiles impinge when propelled along the pressure chamber by the high-pressure gas, the drive surface being connected to, or comprising a part of, a rotatable take-up reel of a vehicle seat belt retractor and arranged to be driven by the impinging projectiles so as to rotate the rotatable take-up reel in a belt retraction
- 20 direction when impinged upon by the projectiles, so as, in operation, to

take up slack in the seat belt webbing, and to pull the seat belt webbing against the vehicle occupant.

In a preferred pretensioner according to the present invention, the drive surface comprises a surface, preferably a circumferential surface, of a wheel 5 which is connected to, or comprises part of, the rotatable take-up reel of the vehicle seat belt retractor. The drive surface may be indented, toothed, grooved, or otherwise shaped, to accept partial intrusion by the projectiles to provide a drive mechanism. The drive surface may be formed with recesses each of which is adapted to receive a single projectile.

10 Alternatively the drive wheel may comprise compliant material deformable by pressure contact between the drive surface and projectile. In one embodiment the drive wheel may comprise at least a circumferential surface layer of compliant material. In another embodiment the drive wheel may comprise a circumferential surface layer of rigid material, and radially inward thereof an 15 annular layer of compliant material.

Suitable compliant materials include resilient material such as rubber, or plastics materials. In another alternative embodiment the drive wheel comprises a circumferential channel having resiliently deformable channel sides, the spacing of the channel sides being such that a projectile can be received therebetween

only by deforming the channel sides. The channel sides may, for example, be spring biased towards each other.

Preferably the projectiles impinge tangentially, or at a low angle of preferably not more than  $10^\circ$  against the drive surface in order to provide a 5 maximum acceleration to the surface.

The pressure chamber preferably comprises an elongate, curved tube of circular cross-section, preferably of steel or other metal capable of withstanding the pressures involved, having an open end arranged in a tangential direction, or at a low angle, to the drive surface. The open end of the tube preferably 10 terminates in an open channel which directs the projectiles against the drive surface. The open channel is preferably provided with a terminal arrest member, positioned so as to slow down the projectiles after they have left the drive surface.

The number of projectiles can be chosen in order to give the required retraction of 15 the seat belt. Preferably there are at least 30, and preferably not more than 50 projectiles, and these are preferably sufficient to rotate the central shaft of the take-up reel by from one and a half to three times, for example, twice, during the activation of the pretensioner. This will result in a compact device capable of optimum retraction effect.

In a preferred embodiment, for example, using a drive wheel and spherical projectiles (balls) which remain in contact one with the next during use, the number of projectiles will depend on inter alia (i) the diameter of the drive wheel or pulley, (ii) the number of required revolutions of the drive wheel, and (iii) the diameter of the projectiles (balls). If the diameter of the drive wheel is "D" the diameter of the projectiles is "d" and the number of revolutions is "N", then the number of balls is given by rounding up the result of applying the formula:

$$\frac{N\pi(D+d)}{d}$$

In an example. N=2, D=50mm and d=10mm, giving a calculated result of 37.7, ie. 38 balls.

Preferably the projectiles are not connected to each other, and most desirably they are spherical in form. This leads to a number of advantages. For example separate unconnected projectiles can be retained in a compact receptacle after actuation of the pretensioner; if they are linked together, a larger or longer receptacle would be required. Projectiles in the form of a row of discrete balls can also articulate more freely than, for example, a chain. The designer is thus provided with greater freedom to shape and position the elongate pressure chamber so as to render the overall design compact, eg by locating parts of the



pressure chamber in positions which would otherwise be inconvenient and therefore not usable for this or any other purpose.

The projectiles are preferably spherical in shape. For example, the projectiles may comprise a series of metal balls, for example, ball bearings, 5 which are arranged in a row in a tubular metal pressure chamber. The diameter of the metal balls is such as to occupy substantially the entire internal diameter of the tube, whilst allowing the balls to travel freely therein.

Advantageously, the pretensioner comprises an arcuate portion of the elongate tube which curves partly or wholly around the drive surface.

10 Advantageously the axis of the elongate tube is disposed in more than one plane.

This can lead to a pretensioner of compact design, for example at least part of the elongate tube may be of helical form, and/or at least part of the elongate tube may be disposed within the take-up reel. Additionally, the gas generating means may be at least partly disposed within the take-up reel.

15 The end of the tube remote from the open end is preferably closed or capped, and a suitable gas-generating composition can be disposed therein. Such a gas-generating composition can comprise, for example, sodium azide, or a gas-generating composition comprising nitroguanidine, as described and claimed in our co-pending UK Patent Application No.9503066 entitled "Gas Generating 20 Composition" filed on the same day as this Application. Alternatively, the

gas-generating composition can be provided in a separate chamber connected to the pressure chamber. The gas-generating composition preferably comprises a pyrotechnic composition ignited by an electronic ignition system activated by a deceleration sensor.

5           After impinging on the drive surface, the projectiles are preferably collected in a collection chamber, or an open cavity, which can conveniently be the housing of the seat belt retractor. The collection chamber or cavity is preferably provided with a clear panel through which the projectiles can be viewed, to provide a functional check on the device.

10           Preferably retaining means are provided for retaining the projectiles in the pressure chamber. Such retaining means may comprise, for example, a rigid foam which is injected into the pressure chamber after the projectiles have been inserted therein.

          The period of activation of the pretensioner is preferably around 20  
15 milliseconds, and the pretensioner is preferably designed to wind in from 120 to 200 mm of seat belt (depending on the amount left on the take-up reel) and cause the belt to lock.

          Preferably when the projectiles are positioned in the collection chamber they provide no impediment or obstacle to the normal operation of the  
20 seat belt, so that after a collision and subsequent actuation of the pretensioner the

vehicle occupant does not continue to be held firmly against the seat. The occupant can thus more readily get out of the vehicle, or continue to drive if possible.

Embodiments of the invention will now be described with reference to 5 and as illustrated in the accompanying drawings in which:

Figure 1 shows a seat belt pretensioner drive mechanism according to the invention in side elevation;

Figure 2 shows the pretensioner of Figure 1 in top elevation;

Figure 3 shows the pretensioner of Figures 1 and 2 in side elevation in 10 an enlarged scale with parts broken away to illustrate the mode of operation;

Figure 4 shows the pretensioner of Figures 1 to 3 in end elevation again with parts broken away to show the mode of operation;

Figure 5 shows a scrap view in section of the gas-generating mechanism.

15 Figure 6 illustrates an alternative form of drive wheel arrangement for a pretensioner according to the invention;

Figure 7 illustrates another form of drive wheel arrangement for a pretensioner according to the invention;

Figure 8 illustrates in end elevation a further form of drive wheel 20 arrangement for a pretensioner according to the invention;

Figure 9 illustrates in side elevation the drive wheel arrangement of Figure 8;

Figure 10 is an end elevation illustrating a pretensioner in accordance with the invention in which the pressure chamber axis is disposed in more than one plane; and

Figure 11 is a side elevation of the pretensioner illustrated in Figure 10.

Referring firstly to Figure 1, the pretensioner illustrated generally at 1 comprises a curved pressure tube 2 which is coiled helically around a drive wheel 3 attached to a shaft 4. The pressure tube 2 is mounted eccentrically of the axis of the drive wheel 3 and has a diameter of curvature slightly greater than the wheel. The tube 2 has a closed end, at which there is situated a cap enclosing a gas-generating mechanism 5, and an open end which is cut back, as illustrated by the broken line 6, to form an open-sided channel 7. At the end of the channel 7 there is provided a projecting arrest member 8. As can be seen from Figure 2, the curved pressure tube 2 describes approximately  $1\frac{1}{2}$  turns about the drive wheel 3. The pretensioner is enclosed in a collection chamber 9, which may comprise the whole or part of the seat belt retractor housing, the chamber 9 having a clear panel 10 for viewing the interior thereof.

Referring now to Figure 3, which depicts the pretensioner in operation, a row of metal balls 11 are illustrated passing along the channel 7 of the pressure

tube 2. There may be, for example, from 30 to 50 of such balls 11 in the pressure tube 2. The balls 11 have a diameter slightly less than the internal diameter of the tube 2 and are freely moveable therein. The drive wheel 3 is provided with a series of circumferential indentations 12 about its periphery, which are spaced 5 apart by a distance such that when adjacent balls 11 are located in the indentations the surfaces of adjacent balls are just touching. The arrangement is shown again in Figure 4 which also shows the drive shaft 4 which is attached to the take-up reel of a seat belt retractor (not shown).

Figure 5 shows a detail of the gas-generating mechanism 5. A 10 pyrotechnic gas-generating composition 13 is packed into a pressure-resistant plug 14 firmly mounted at the end 15 of the pressure tube 2. The pyrotechnic composition 13 is ignited by an electronic igniter (not shown) which is activated by a deceleration sensor (not shown). A felt plug 16 is positioned at the end 15 of the pressure tube 2 and serves as a limit member for the travel of the row of balls 15 11.

In the rest, or inactive, position of the pretensioner, the balls 11 are confined within the pressure tube 2 by a rigid foam 17 which is injected into the pressure tube 2 after the balls have been inserted and which solidifies to retain the balls 11 in the pressure tube. The plug 16 prevents the foam from reacting the 20 pyrotechnic composition. With the balls 11 retained in the tube 2, the drive wheel 3 and shaft 4 are able to rotate freely with the take-up reel of the seat belt

retractor. The ball retaining means may alternatively comprise, for example, a frangible plug, or a spring means, which is compressed as the balls are ejected from the pressure tube.

In the event of a collision, the deceleration sensor activates the  
5 electronic igniter which in turn sets off the pyrotechnic gas-generating composition 13. The volume of gas generated by the composition 13 is sufficient to displace the felt plug 16, and propel the row of balls 11 at considerable speed along the pressure tube 2. The foam 17, of course, disintegrates as the balls are ejected from the pressure tube 2. When the balls reach the open channel 7 they  
10 come into contact with the indentations 12 on the drive wheel 3 and cause the drive wheel 3 and drive shaft 4 to rotate at high speed. The drive shaft rotates the take-up reel of the seat belt retractor causing retraction of the seat belt by the desired amount.

The path of the balls is tangential to the circumference of the drive  
15 wheel 3 and as they fly off they each come into contact with the arrest member 8 at the end of the open channel 7 and suffer a substantial deceleration. This prevents the balls from damaging the wall of the collection chamber 9. The pretensioner is preferably enclosed within the housing of the seat belt retractor, which comprises the collection chamber 9, and as the balls are ejected from the  
20 open channel 7, they collect in the bottom of the housing from where they can be viewed through the clear panel 10 to provide a visual check on whether the

pretensioner has been activated. After use, they can be recovered and reused with a fresh charge of pyrotechnic composition as appropriate.

After the last ball has left the periphery of the drive wheel 3 there is no further force acting on the drive wheel which is then locked in position by the 5 seat belt retractor lock. When the vehicle has come to a halt, the seat belt retractor lock is released and the seat belt can again be used normally. The projectiles 11 are by this stage clear of the drive surface and thus do not interfere in any way with such normal use.

Figure 6 illustrates an alternative form of drive which comprising a drive wheel 10 20 which has a circumferential surface layer 21 of a compliant material. In use, balls 11 are propelled in the direction of the arrow A along a pressure tube 2 by means of pressure generated by a gas-generating mechanism 5, as described with reference to Figure 1 to 5.

When the balls encounter the surface layer 21, they are constrained 15 between the wall of the tube 2 and the layer 21, so as to exert a radially inward pressure thereon as well as a forward pressure tending to rotate the wheel 20 in the direction of the arrow B.

The compliant material of the surface layer 21 thus deforms as illustrated so as to create an indentation 22 which receives a ball 11, and a lip 23

which resists free passage of the ball past the wheel. Each successive ball 11 thus drives the wheel 20 to rotate in the direction of the arrow B until rotation of the wheel enables the ball to escape, past the lip 23, and a subsequent ball 11 then repeats the cycle. The wheel 20 drives the take-up reel (not shown) via a shaft 5 29 on which the wheel is mounted.

The compliant layer in this embodiment should be soft enough to deform under the action of the balls 11 as illustrated, but needs relatively high shear strength so that the lip 23 does not shear off under the load imposed by the balls 11. Suitable materials for the compliant layer are resilient materials such as 10 polypropylene, polyethylene (especially UHMPE – ultra high modulus polyethylene), and reinforced rubber ( eg fabric-reinforced).

As illustrated in Figure 7, a drive wheel 24 for use in the invention comprises a circumferential surface layer 25 of rigid material such as steel or hard plastics material, and an inner hub zone 26 of a similar material. 15 Sandwiched between the hub 26 and the circumferential layer 25 is an annular layer 27 of compliant material, which may be a material similar to that of the layer 21. In use, when the pretensioner is actuated, the balls 11 are driven in the direction of the arrow A into the space between the wall of the pressure tube 2 and the layer 25. This space is designed to be somewhat narrower than the 20 diameter of the balls 11, so that the material 27 must deform in order to admit the balls into this space. A pressure load is thus created between the balls 11 and the



layer 25 whereby successive balls drive the wheel 24 to rotate in the direction of the arrow B, until each successive ball escapes from the pinch between the rim 25 and the tube 2.

As illustrated in Figures 8 and 9, a drive wheel 30 comprises a rigid hub 31, 5 mounted on a drive shaft 32 which drives the take-up reel (not shown) to rotate. Mounted adjacent the hub 31 are a pair of discs 33 of resilient material such as spring steel. The discs are fixed to the hub only near the shaft 32, and they define between their radially outer portions 33 and the circumference of the hub 31, a circumferential channel 34. The portion 33 constitute channel sides, and a ball 11 10 can be received into the channel only by deforming the channel sides to move apart in the direction of the arrows x, as shown in Figure 8. When the pretensioner is actuated, the balls 11 are propelled along the tube 2 in the direction A as previously described. The tube 2 opens adjacent to the wheel 30, and is so spaced therefrom that the tube wall forces the balls to enter the channel 15 34 to its full depth, so that the channel sides 33 are sprung apart. By virtue of the friction thus created between the channel sides 33 and the balls 11, the balls thus drive the wheel 30 to rotate in the direction of the arrow B. The balls escape from the pinch between the tube 2 and the channel 34 into a collection area 35, partly shown in Figure 9. Their removal from the channel 34 is ensured by means 20 of a stripper plate 36. Friction material can be applied to the surfaces of the channel sides 33, as illustrated at 37.

The embodiments illustrated in Figures 6 to 9 all have a homogeneous circumference, i.e. without individual teeth or recesses for receiving individual balls separately. This has the considerable advantage that the balls 11 can engage readily with the drive surface of the drive wheel in each case, without the risk that a ball, especially the first ball, may encounter the drive surface at a location between two individual teeth or recesses which could cause jamming or damage to the mechanism.

In addition, a further considerable advantage is that the tension load which the device can apply to a seat belt is limited by the maximum torque which can be applied between the balls and the drive wheel. If this maximum is exceeded, the balls simply escape from the pinch between the drive wheel and the pressure tube in each of these embodiments. This provides a further safety feature in that the user is protected against the possibility of excessive tightening of the belt and the output torque of the wheel is independent of the maximum pressure produced by the gas generator.

As shown in Figures 10 and 11, a drive wheel 40 is formed of a compliant material (for example UHMPE) and has a continuous part-circular-section groove 41 formed in its periphery for receiving balls 11. The wheel 40 is mounted on a take-up reel 42 of a seat belt retractor.

A gas generator 43 containing pyrotechnic material 44 is housed within the reel 42, together with the first section 44 of an elongate tube of circular cross-section 44 of an elongate tube of circular cross-section which constitutes the pressure chamber 2. The tubular pressure chamber 2 is bent so as to pass  
5 radially outward from the reel and then back on itself so as partially to embrace the circumference of the drive wheel. Balls 11 (only two are shown for clarity) are driven, upon actuation of the gas generator 44, in the direction of the arrow A, so as to pass into the pinch between the rim 41 and the open end 45 of the tube 2, so as to drive the wheel 40 and the reel 42, to rotate in the direction of the arrow  
10 B, in similar manner to the embodiment of Figure 6. The used balls 11 are collected in a receptacle 46.

The combination of spherical projectiles 11 in a circular-section tube, the projectiles not being connected to each other, permits that the pressure tube is strong in resisting the pressure of the gas generator, and can be bent into  
15 three-dimensional shapes while the individual balls have no restriction on their relative articulation which limits the shape which can be adopted for the tube 2. Thus the gas generator 43 can be located inside the reel 42, together with part of the pressure tube 2. This space would otherwise not be used, and the overall bulk of the pretensioner is thus substantially less than would otherwise be the case.

20

The reader's attention is directed to all papers and documents which are filed concurrently with or previous to this specification in connection with this

application and which are open to public inspection with this specification, and the contents of all such papers and documents are incorporated herein by reference.

All of the features disclosed in this specification (including any  
5 accompanying claims, abstract and drawings), and/or all of the steps of any method or process so disclosed, may be combined in any combination, except combinations where at least some of such features and/or steps are mutually exclusive.

Each feature disclosed in this specification (including any  
10 accompanying claims, abstract and drawings), may be replaced by alternative features serving the same, equivalent or similar purpose, unless expressly stated otherwise. Thus, unless expressly stated otherwise, each feature disclosed is one example only of a generic series of equivalent or similar features.

The invention is not restricted to the details of the foregoing  
15 embodiments. This invention extends to any novel one, or any novel combination, of the features disclosed in this specification (including any accompanying claims, abstract and drawings), or to any novel one, or any novel combination, of the steps of any method or process so disclosed.

**CLAIMS**

1. A pretensioner (1) for a vehicle seat belt retractor of the type having a rotatable take-up reel on which seat belt webbing can be wound, which comprises:
- 5 (i) an elongate pressure chamber (2);
- (ii) a plurality of projectiles(11) located in the pressure chamber;
- (iii) gas generating means (5) for generating a high-pressure gas within the pressure chamber so as to propel the projectiles along the pressure chamber;
- 10 (iv) a drive surface (12; 21; 25; 34;41) upon which the projectiles impinge when propelled along the pressure chamber by the high-pressure gas, the drive surface being connected to, or comprising a part of, a rotatable take-up reel (42) of a vehicle seat belt retractor and arranged to be driven by the
- 15 impinging projectiles (11) so as to rotate the rotatable take-up reel in a belt retraction direction when impinged upon by the projectiles, so as, in operation, to take up slack in the seat belt webbing, and to pull the seat belt webbing against the vehicle occupant.
- 20 2. A pretensioner according to Claim 1, in which the drive surface comprises a circumferential surface (12; 21; 25; 34; 41) of a drive

wheel which is connected to, or comprises part of, a rotatable take-up reel (42) of a vehicle seat belt retractor.

3. A pretensioner according to Claim 1 or Claim 2, in which the drive surface is indented, toothed, grooved, or otherwise shaped, to accept partial intrusion by the projectiles.
4. A pretensioner according to claim 3 in which the drive surface is formed with recesses (12) each of which is adapted to receive a single projectile.
5. A pretensioner according to claim 1 or Claim 2 in which the drive wheel comprises compliant material (21; 27; 33; 40) deformable by pressure contact between the drive surface and a projectile.
6. A pretensioner according to claim 5 in which the drive wheel comprises at least a circumferential surface layer (21) of compliant material.
7. A pretensioner according to claim 5 in which the drive wheel comprises a circumferential surface layer (25) of rigid material, and radially inward thereof an annular layer (27) of compliant material.

8. A pretensioner according to claim 5 in which the drive wheel comprises a circumferential channel (34) having resiliently deformable channel sides (33), the spacing of the channel sides being such that a projectile (11) can be received therebetween only by deforming the channel sides (33).
9. A pretensioner according to claim 8 in which the channel sides (33) are spring biased towards each other.
10. A pretensioner according to any of the preceding claims, in which, in operation, the projectiles (11) impinge tangentially against the drive surface (12; 21; 25; 34; 41)..
11. A pretensioner according to any of the preceding claims, in which the pressure chamber comprises an elongate tube (2) of circular cross-section.
12. A pretensioner according to Claim 11, in which the tube (2) has an open end arranged in a tangential direction to the drive surface.
13. A pretensioner according to Claim 11 or Claim 12, in which the tube terminates in an open channel (7), which, in operation, directs the projectiles against the drive surface.

14. A pretensioner according to claim 13 in which the open channel (7) is provided with a terminal arrest member (8;36) , positioned so as, in operation, to slow down the projectiles (11) after they have left the drive surfaces.
- 5 15. A pretensioner according to any one preceding claim in which the number of projectiles (11) is sufficient to rotate the take-up reel of the seat belt retractor by between one and a half and three times during the activation of the pretensioner.
16. A pretensioner according to any one preceding claim which comprises  
10 at least 30 projectiles (11).
17. A pretensioner according to claim 16 which comprises not more than 50 projectiles (11).
18. A pretensioner according to any one preceding claim wherein the projectiles (11) are not connected to one another.
- 15 19. A pretensioner according to any one preceding claim wherein the projectiles (11) are spherical in form.



20. A pretensioner according to claim 19 in which the spherical projectiles (11) are arranged in a row in an elongate pressure tube (2) and the diameter of the projectiles(11) is such as to occupy substantially the entire internal diameter of the tube (2) whilst allowing the projectiles to travel freely therein.
- 5
21. A pretensioner according to the claim 20 which the elongate pressure tube (2) comprises an arcuate portion which curves partly or wholly around the drive surface.
22. A pretensioner according to claim 20 or 21 in which the axis of the elongate tube is disposed in more than one plane.
- 10
23. A pretensioner according to claim 22 wherein at least part of the elongate tube (2) is of helical form.
24. A pretensioner according to claim 22 or 23 in which part of the elongate tube (2) is disposed within the take-up reel (42).
- 15 25. A pretensioner according to any one of claims 22 to 24 in which the gas generating means (43) are at least partly disposed within the take-up reel (42).

31. A pretensioner according to Claim 28, in which the collection chamber is provided with a clear panel (10) through which the projectiles can be viewed.
32. A pretensioner according to any of the preceding claims, in which the projectiles (11), after operation of the pretensioner, are positioned such that they provide no impediment or obstacle to the normal operation of the seat belt.
33. A pretensioner according to any of the preceding claims, substantially as hereinbefore described and as illustrated in the accompanying drawings.
34. A vehicle seat belt pretensioner substantially as hereinbefore described.
35. A vehicle seat belt retractor provided with a pretensioner according to any of Claims 1 to 34.
36. A seat belt retractor according to Claim 35, in which, in operation, the action of the seat belt pretensioner rotates the take-up reel of the seat belt retractor by from 1 to 3 times within a period of 20 milliseconds.

26. A pretensioner according to any of the preceding claims, in which a gas-generating composition (13) is disposed within the pressure chamber (2).
27. A pretensioner according to any of the preceding claims, in which the  
5 gas-generating composition (13) comprises a pyrotechnic composition.
28. A pretensioner according to any of the preceding claims, in which retaining means (17) are provided to retain the projectiles (11) within the pressure chamber (2) prior to activation of the pretensioner.
29. A pretensioner according to Claim 26, in which the retaining means  
10 comprises a rigid foam(17) which is injected into the pressure chamber (2) after the projectiles (11) have been inserted therein and which solidifies to retain the projectiles in the pressure chamber.
30. A pretensioner according to any of the preceding claims, that is  
15 provided with a collection chamber (9; 35; 46), which, in operation, is adapted to receive the projectiles (11) after they have impinged on the drive surface.

- 37.** A seat belt retractor according to Claim 35 or 36, in which, in operation, the pretensioner is adapted to wind in from 120 to 200 mm of seat belt.
- 38.** A vehicle seat belt retractor according to any of Claims 35 to 37,  
5 substantially as hereinbefore described with reference to and as illustrated in the accompanying drawings.
- 39.** A vehicle seat belt retractor substantially as hereinbefore described.

Fig.1.

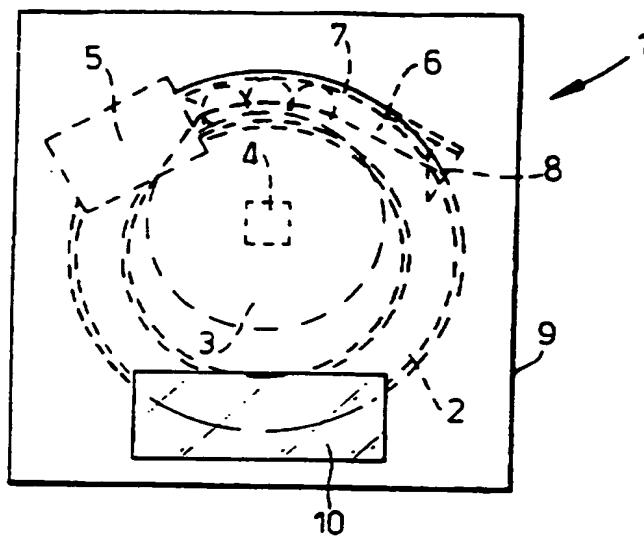


Fig.2.

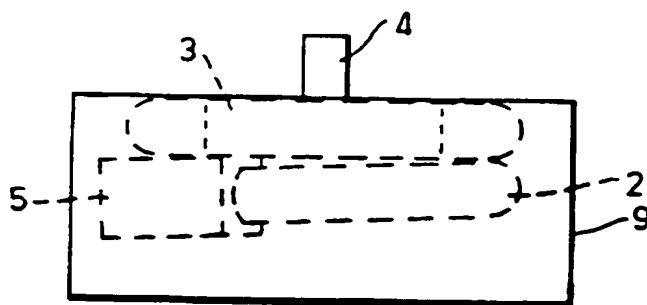


Fig.3.

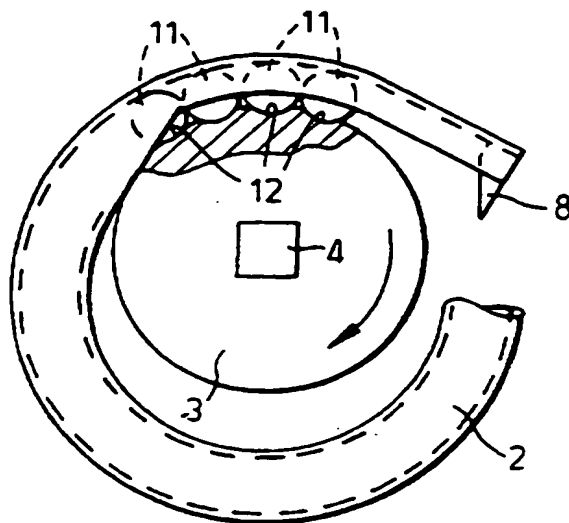


Fig.4.

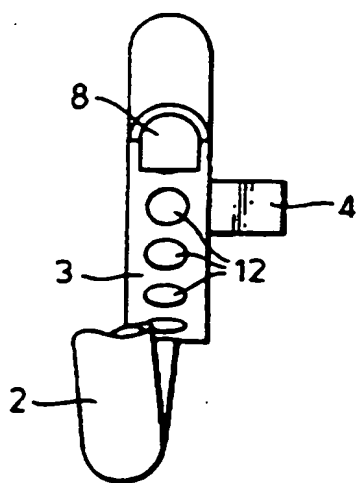


Fig.5.

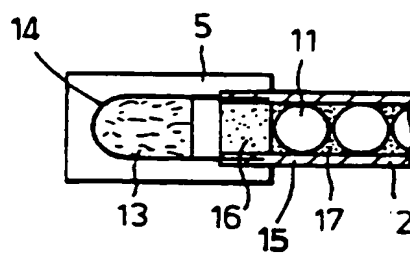


Fig.6.

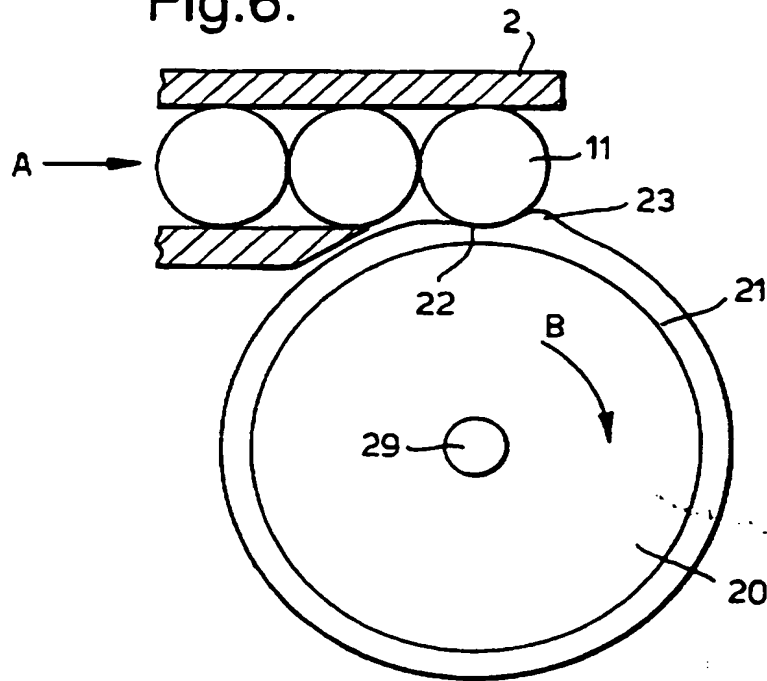
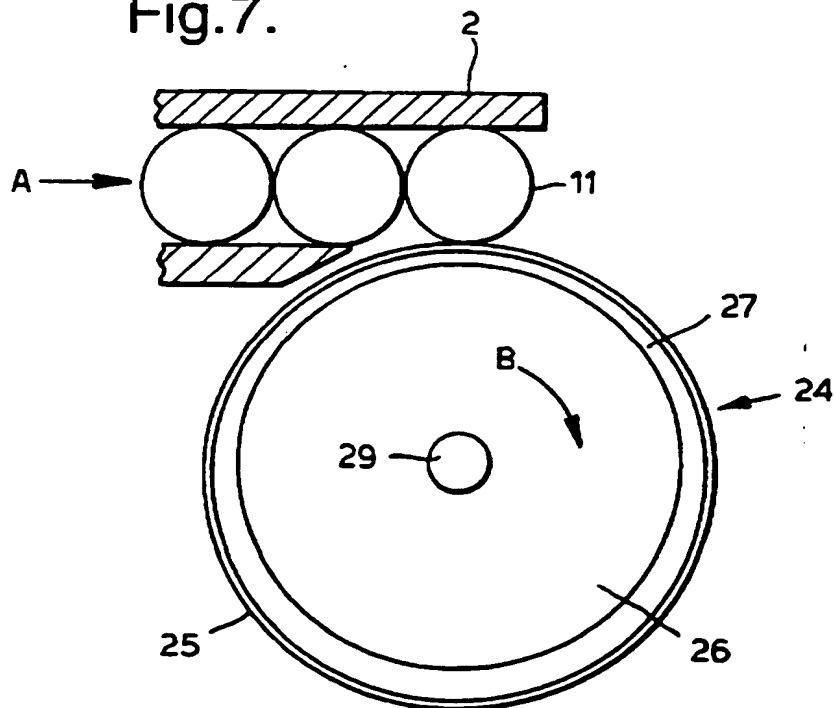


Fig.7.



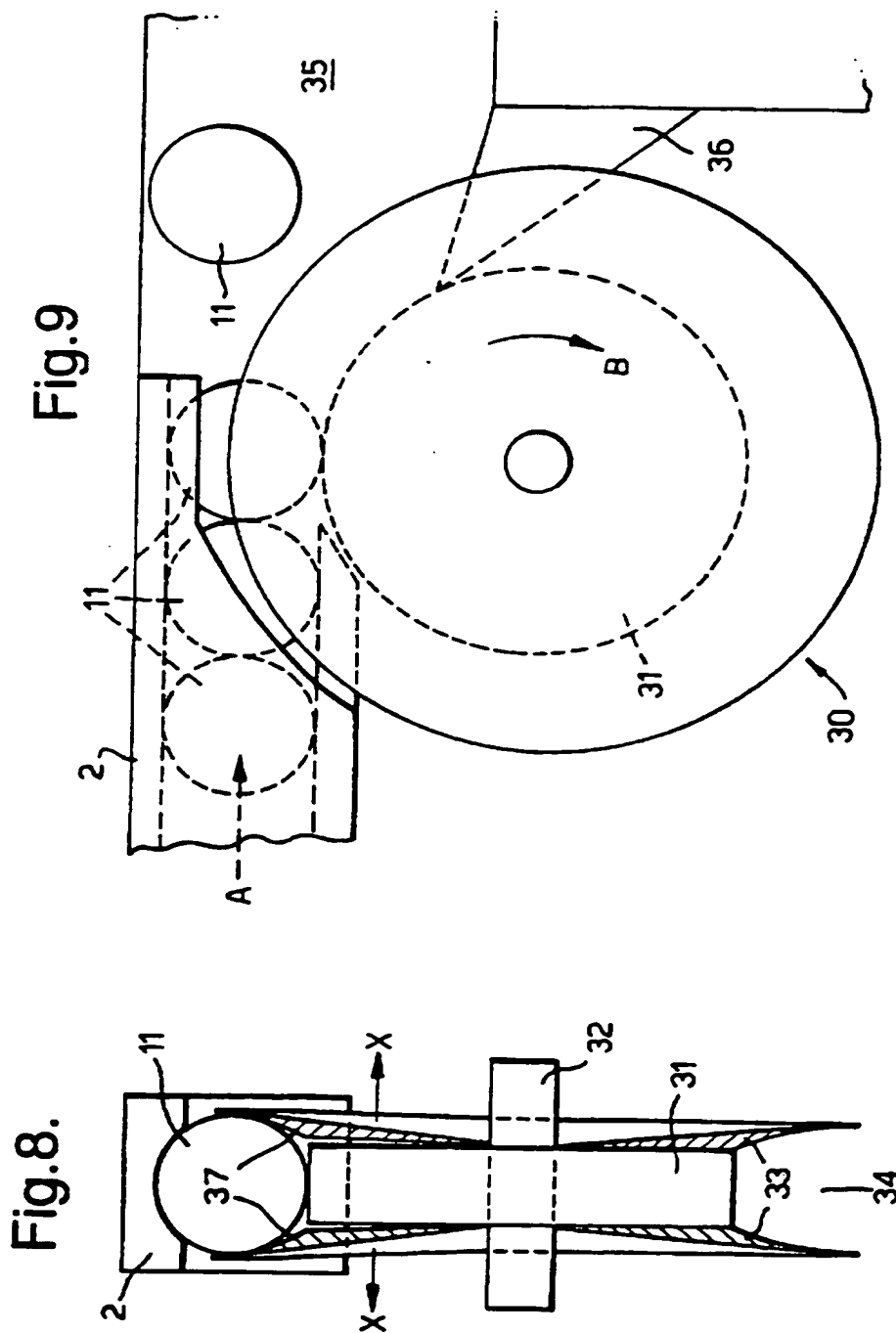




Fig.10.

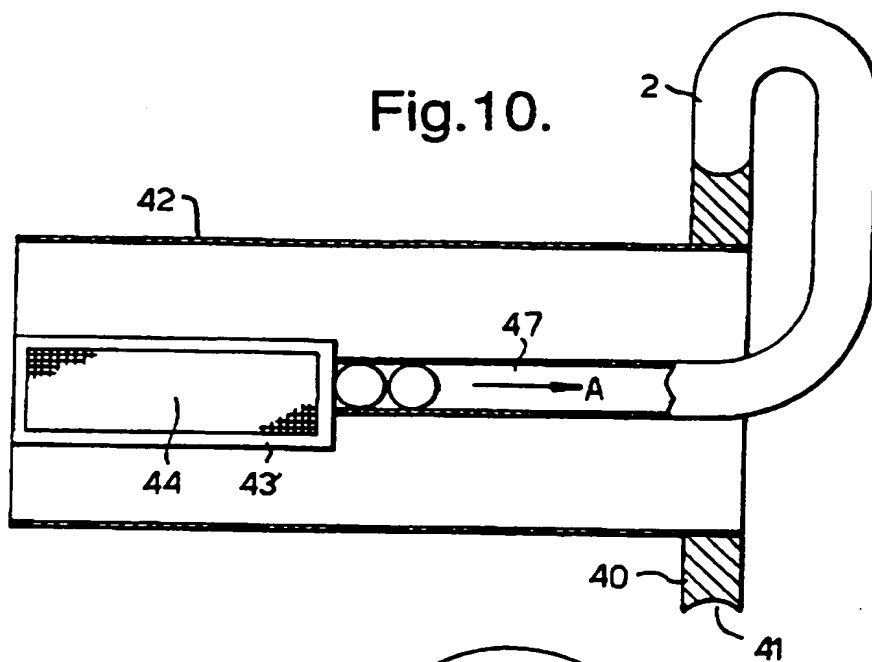


Fig.11.

